

# RESORT AT SQUAW CREEK SITE REPORT

May 2008

## INTRODUCTION

This report describes monitoring results from the Resort at Squaw Creek test plots (Figure 1). The test plots are located at the Resort at Squaw Creek in Placer County, California. This area includes two separate sets of plots: the Old Reveg test plots, built in 1991, and the Snow King test plots, built in October 2002. All test plots are located on Juniper Mountain Saddle downhill from Juniper Mountain Road and uphill from the Resort at Squaw Creek facilities.



**Figure 1. Satellite image of the Resort at Squaw Creek location in relation to Lake Tahoe.**

The Old Reveg plots were completed in 1991 with a surface hydroseed treatment commonly applied on the Resort at Squaw Creek ski runs. This surface treatment is similar to the Caltrans Erosion Control Type D treatment. In 2003, woodchips were ripped into one of the Old Reveg plots, and the other

plot was left as a control for the surface treatment. In 2006, a slump formed in the bottom half of the Old Reveg plot amended with woodchips. The Snow King test plots were designed to evaluate the effectiveness of different amendments in controlling erosion. One plot was amended with woodchips, one with compost, and the last one with a mix of 50% compost and 50% woodchips. All of the Snow King test plots were tilled, fertilized, seeded, and mulched.

## **PURPOSE**

These test plots were installed to investigate the differences in sediment source control and erosion control capacity between the following three types of treatments:

- 1) Surface hydroseed treatments (comparable to Caltrans Erosion Control D)
- 2) Surface hydroseed treatments re-treated by ripping the soil and incorporating woodchips (ripping is a method of soil loosening)
- 3) Ripped plots with organic matter (woodchips, compost, or both) incorporated into the soil and an application of organic fertilizer, native seed, and pine needle mulch

The following measures were used to determine the effectiveness of each treatment type: infiltration rate, sediment yield, soil density, soil nutrient levels, ground cover by mulch, foliar cover by plants, and soil shear strength.

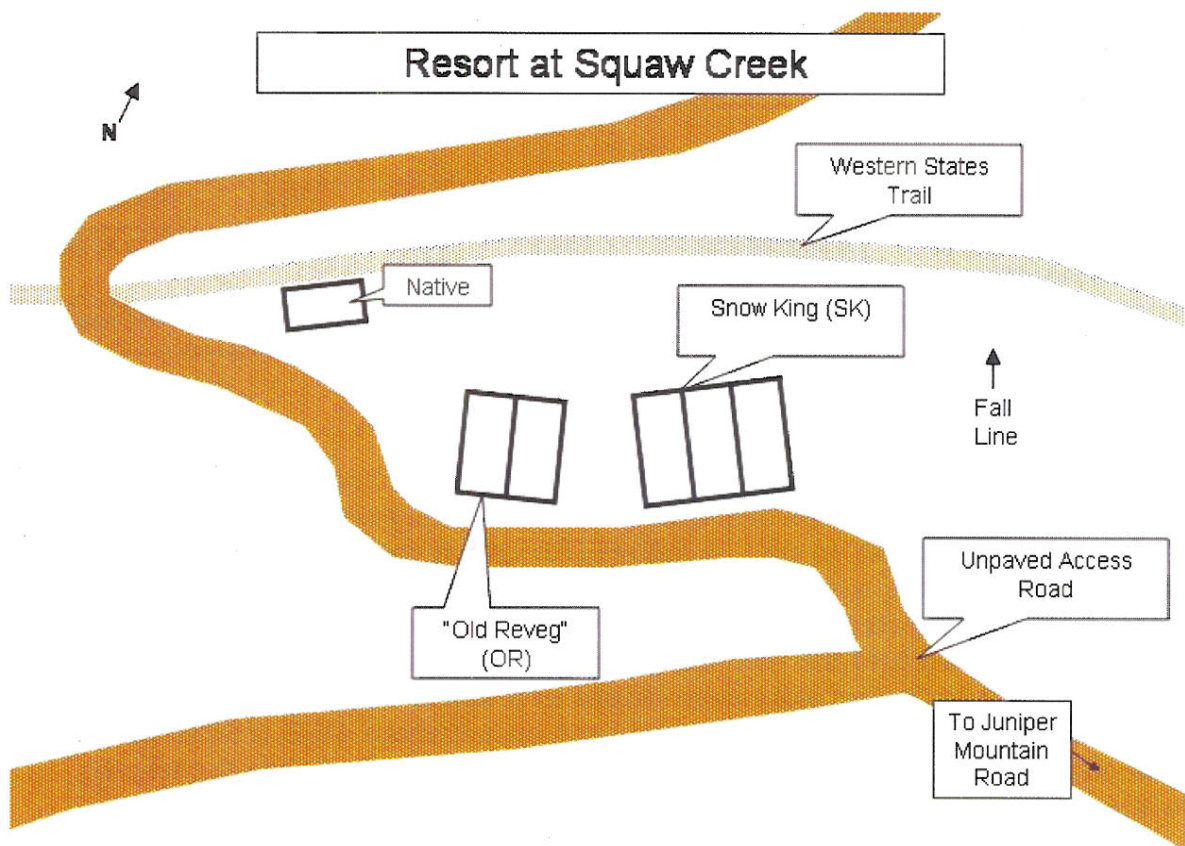
The following questions will be answered by studying these plots:

- 1) Is there a difference in erosion control capacity between the hydroseed treatment (Old Reveg), the hydroseed treatment with ripping (Old Reveg), and the ripped plots with amendments (Snow King)?
- 2) Is there a difference in erosion control capacity among different ripped plots with different combinations of compost and woodchips incorporated into the soil?

## **SITE DESCRIPTION**

The Resort at Squaw Creek is a year-round resort complex located in Olympic Valley, California (eastern Placer County) within the South Fork Squaw Creek watershed. Part of the resort consists of a ski complex know as Snow King, which is interconnected with the Squaw Valley ski resort. Both sets of test plots are located on a northwest facing ski slope with an average slope angle of 19 degrees (Figure 2) and similar solar exposures. The site elevation is about 6,900 feet (2,103 meters) above mean sea level (AMSL). The soils are rocky with about 30 percent coarse material (greater than ½ inch or 1.27 cm diameter) and are derived from volcanic parent material. The soil is classified as sandy loam and contains 19% clay, 22% silt, and 58% sand. A nearby native site with a 20 degree slope, an elevation of 6,676 feet (2,034 meters) AMSL, and a

northwest aspect was used as a reference site. Local native vegetation consists of white fir (*Abies concolor*) greenleaf manzanita (*Arctostaphylos patula*), and native bunchgrasses and forbs. Many of the surrounding ski slopes were treated with a hydroseed surface treatment that contains wheatgrass species (*Agropyron intermedium*/*Elytrigia intermedia* ssp. *intermedia* and *Agropyron dasystachyum*/*Elymus lanceolatus*) that are not native to the local area.



**Figure 2. Overview of Juniper Mountain treatment and native monitoring areas.**

## **METHODS & MATERIALS**

### **Treatments**

#### **Old Reveg**

The Old Reveg (OR) area contains two plots: OR1 and OR2 (Figure 2). Old Reveg 2 is a control plot that was constructed in 1991 using a hydroseed surface treatment (Table 1). It is representative of traditional slope stabilization/erosion control treatments used locally on many ski slopes and road cuts. Thickspike wheatgrass (*Agropyron dasystachyum*/*Elymus lanceolatus*) and intermediate

wheatgrass (*Agropyron intermedium* / *Elytrigia intermedia* ssp. *intermedia*) were seeded in this treatment. Old Reveg 1 has the same surface treatment as OR2, but 12 years after construction it was ripped with woodchips to a depth of 12 inches (30 cm).

**Table 1. Treatment descriptions**

Plot Code	Treatment	Amendment	Soil Loosening	Native Seed	Organic Fertilizer	Mulch
OR1	Woodchips Rip	Woodchips	Ripping	None	None	Unknown
OR2	Surface Treatment	None	None	None	None	Unknown
SK1	Compost Only	Compost	Tilling	Yes	Yes	Pine needle
SK2	Compost and Woodchips	Compost and Woodchips	Tilling	Yes	Yes	Pine needle
SK3	Woodchips Only	Woodchips	Tilling	Yes	Yes	Pine needle

### **Snow King**

The Snow King (SK) area consists of three test plots, constructed in October 2002. Compost, woodchips or a combination of both were applied to each plot (Table 1 and Figure 2). In SK1, 3 inches (7.6 cm) of compost were incorporated into the soil. In SK2, a mixture of 50% compost and 50% woodchips, 3 inches deep, was incorporated into the soil. In SK 3, 3 inches (7.6 cm) of woodchips were incorporated into the soil. Once amendments had been placed on the surface of the plots, the plots were ripped to a depth of 12 inches (30 cm) using specially constructed ripper tines mounted on a Kubota 4WD tractor with a rear-mounted winch (Figure 3). The winch was used to stabilize the tractor while ripping the steep slope.

Following ripping and incorporation of the soil amendments, Biosol was applied evenly over the area at a rate of 1,500 lbs/acre, (1,684 kg/ha) and lightly raked into the soil. A native grass seed mix was then applied at a rate of 100 lbs/acre (112 kg/ha). The mix consisted of equal amounts of squirreltail (*Elymus elymoides*), mountain brome (*Bromus carinatus*) and blue wildrye (*Elymus glaucus*). Approximately 5 lbs/acre (5.6 kg/ha) of antelope bitterbrush (*Purshia tridentata*) was also included. All seed was lightly raked into the soil surface. Following seeding, the entire treatment area was mulched with pine needles to a depth of approximately 1 inch (2.5 cm) using a Shred-vac mulch blower. All plots were then tackified.

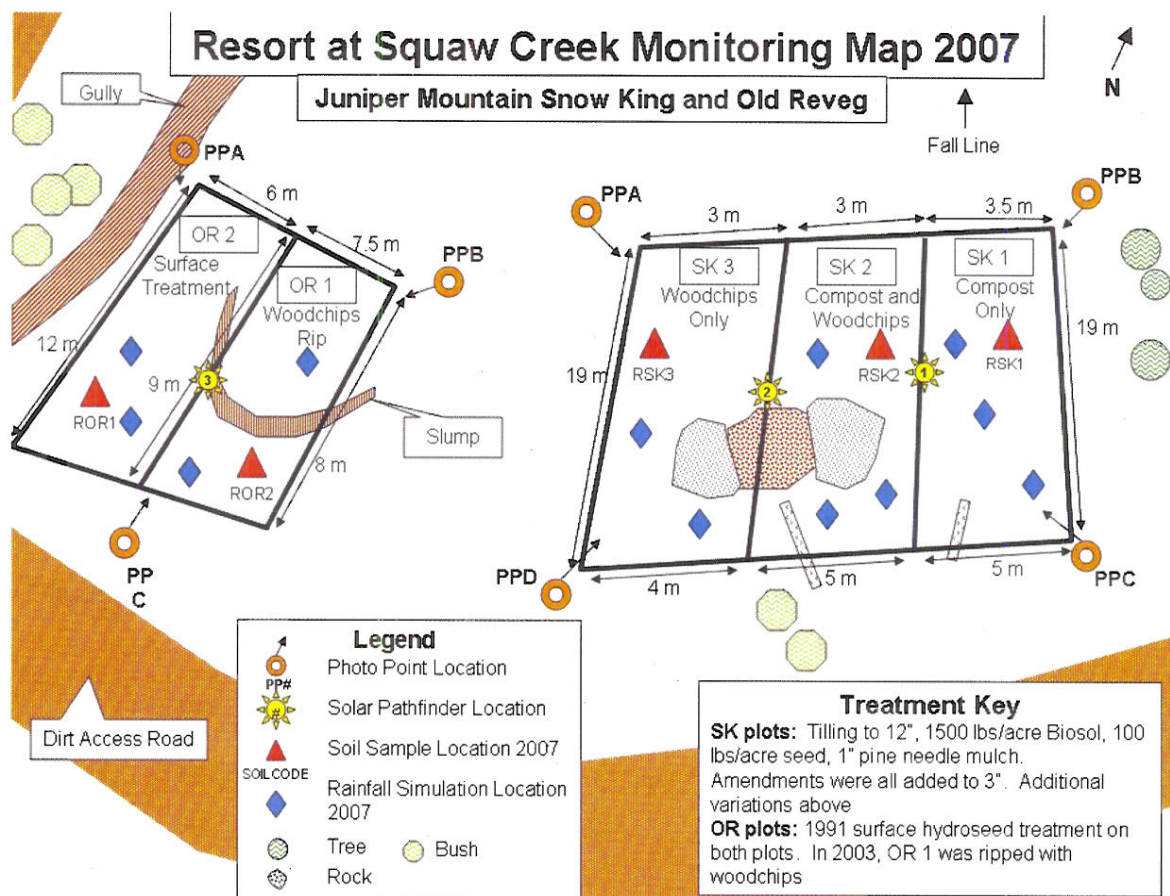
A native site with similar slope and aspect was selected and used as a reference for treatment performance in 2006 (Figure 2 and Figure 4).



**Figure 3. Winched Kubota tractor ripping the soil on the Snow King plots.**



**Figure 4. Native reference plot with mature shrubs and trees.**



**Figure 5. 2007 Monitoring and Treatment Map. Treatments, photo point locations, rainfall locations, and soil sample locations are shown.**

## **Monitoring**

The Resort at Squaw Creek test plots have been monitored periodically since 2003. A consistent monitoring program that includes site assessment, plant cover, soil density, soil moisture, photo documentation, and rainfall simulation was implemented in 2006 and continued through 2007. In 2007, soil shear strength was also measured.

All monitoring was conducted in metric units, while treatment applications were calculated in English units. Both metric and English units are presented in the text. Some tables, such as those for the seed mixes are only presented in English units.

## **Cover**

Cover point monitoring is a statistically defensible method of measuring plant and foliar cover (hereafter referred to as either “plant cover” or “foliar plant cover”), plant composition and mulch cover. Cover data is used in combination with rainfall simulation data to establish whether there is a relationship between sediment yield and cover.

Cover point monitoring was conducted at the Resort at Squaw Creek test plots in 2005, 2006, and 2007. Cover was measured using the cover point method along randomly located transects.<sup>1</sup> The cover pointer consists of a metal rod with a laser pointer mounted 3.3 feet (1 m) high. After the rod is leveled in all directions, the button on the laser pointer was depressed and two cover measurements were recorded (Figure 6 and Figure 7):

1. The first hit cover, which represents the first object intercepted starting from a height of 3.3 feet (1 m) above the ground and
2. The ground cover hit.

The first hit cover measures the foliar cover by plants (leaves and stems). It does not measure the part of the plant actually rooted in the ground. The ground cover hit measures whatever is lying on the ground or rooted in the ground (i.e. litter/mulch, bare ground, basal (or rooted) plant cover, rock and woody debris).

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<sup>1</sup> Hogan, Michael. Luther Pass Monitoring Report: Plant and Soil Cover Monitoring for Evaluating Sediment Source Control Success in the Lake Tahoe Basin. 2003. South Lake Tahoe, CA, Lahontan Regional Water Quality Control Board.



**Figure 6. Cover pointer in use along transects.**



**Figure 7. Cover pointer rod with first hit cover and ground cover hit by the laser pointer. The laser pointer hits are circled in red. The first cover hit is a native grass and the ground cover hit is pine needle mulch.**

Total ground cover comprises all cover other than bare ground. Plant cover both on the ground and foliar was recorded by species and then organized into cover groups based on four categories: lifeform, perennial/annual, native/alien (2007 only), and seeded/volunteer (2007 only). Perennial herbaceous species includes seeded grasses, native grasses and forbs, and any non-native perennial species. Annual herbaceous species include native annuals such as Douglas knotweed (*Polygonum douglasii*) and invasive species such as cheatgrass (*Bromus tectorum*). Woody species are any tree and shrub species of interest, native or introduced. Each species was then classified based on whether it is native to the Tahoe area, and whether it was seeded during treatment. Data is also presented on the amount of cover by species. Species of interest are species that were seeded and problem species such as cheatgrass. An ocular estimate of cover at each plot was also recorded and includes many species not hit using cover point sampling. The species list as well as the ocular estimates of cover by species is presented in Appendix A.

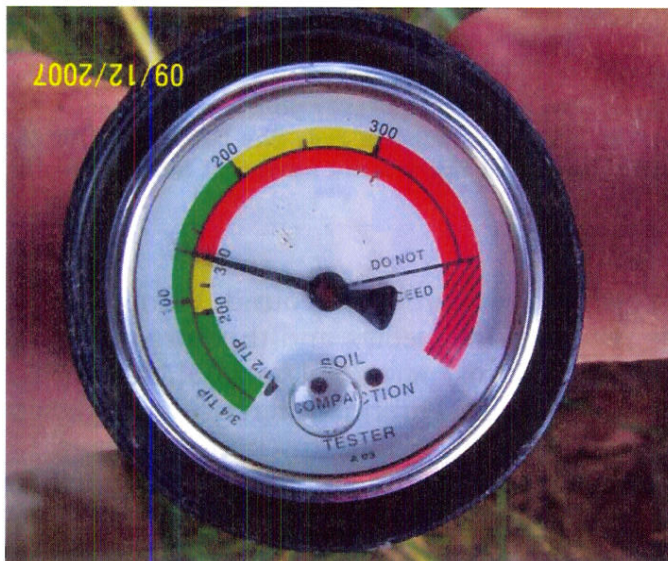
## **Soil and Site Physical Conditions**

### Soil Density

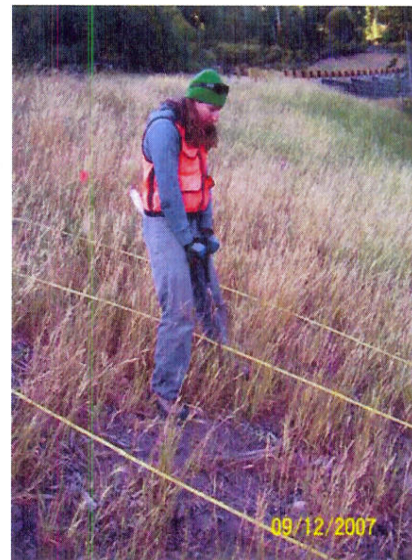
The penetrometer depth to resistance (DTR) is often used as an index of soil density. A denser soil is less likely to allow infiltration. Rainfall simulations

conducted on road cuts in Oregon found increased infiltration rates in soils with penetrometer depths to refusal (DTRs) greater than 4 inches (10 cm).<sup>2</sup>

In 2006 and 2007, soil density and soil moisture were measured along the same transects as the cover point data for all of the plots. Penetrometer data was collected in 2005; however, a different collection method was used. Therefore, the 2005 data is not presented. A cone penetrometer was used to measure the depth to refusal, which is used as an index for soil density. The cone penetrometer with a ½ inch diameter tip was pushed straight down into the soil until a maximum pressure of 350 pounds per square inch (2,411 kPa) was reached (Figure 8 and Figure 9). The depth at which that pressure was reached was recorded as the depth to refusal (DTR). These depth measurements were used as an index for soil density.



**Figure 8. Cone penetrometer dial, showing pressure applied in pounds per square inch.**



**Figure 9. Conducting cone penetrometer readings along transects.**

### Soil Moisture

A hydrometer was used to measure volumetric soil moisture content adjacent to the penetrometer readings at a depth of 4.7 inches (12 cm) (Figure 10).

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<sup>2</sup> Grismer, M. Simulated Rainfall Evaluation at SunRiver and Mt Bachelor Highways, Oregon. Unpublished.

### Soil Strength

Soil strength can be an important indication of a soils resistance to mass slope failure under high moisture conditions. Soil strength or a soils resistance to a shear force can be attributed to the internal structure of the soil, to woody material embedded in the soil, or to the presence of plant roots. The density of plant roots has been shown to increase soil strength in laboratory tests.<sup>3</sup>

In 2007, soil strength was tested along cover point transects in the same manner as soil density and soil moisture. A hand-held shear vane with 1.5 inch (38mm) long blades was pushed into the soil to a depth of 3 inches (76mm) and turned until the soil could no longer resist the force exerted by the blades and the soil structure fractured or deformed (Figure 11). This force was then recorded as the “shear stress” in kilopascals (kPa). Forty kPa was the maximum force the shear vane could measure. Any values above 40 kPa were recorded at 40 kPa and noted as such. This method of determining shear strength has been regularly used in agricultural soils and various laboratory tests.<sup>4</sup> This method of testing soil shear strength has not been applied to many forest soils.

### Solar Exposure

In 2007, solar radiation measurements were taken at each set of plots. These measurements were taken using a Solar Pathfinder (Figure 12). In 2006, solar radiation was recorded at the native site. Since solar input affects evaporation rates and soil temperature, which may affect time of seed germination, germination rate, rate of plant growth, and soil microbial activity, it is an important variable to consider when monitoring plant growth and soil development.



**Figure 10. Conducting soil moisture readings along transects.**



**Figure 11. Soil shear strength tester in use.**



**Figure 12. Solar pathfinder in use.**

<sup>3</sup> Tengbeh, G.T. 1993. The Effect of Grass Roots on Shear Strength Variations with Moisture Content. *Soil Technology*. Vol. 6. pp. 287-295.

<sup>4</sup> Ibid. pp. 287-295.

### Soil Nutrient Analysis

Successful re-vegetation requires that nutrient capital be stored in the soil for release over time. Sufficient organic matter and a healthy microbial community are necessary to provide a long-term source of nitrogen. Previous studies of soil nutrient levels at re-vegetation sites throughout the Tahoe area found that sites with high plant cover had significantly higher soil nutrients over the long term than soils with lower soil nutrient levels.<sup>5</sup> Total Kjeldahl nitrogen and organic matter were used as indicators of soil health in this study. Total Kjeldahl nitrogen (TKN) is a measure of readily available nitrogen. Three soil sub-samples were taken from each plot; therefore, differences in TKN and organic matter values may be a result of the variability within a plot.

Soil sub-samples were taken from each plot of the mineral soil beneath any mulch layer to a depth of 12 inches (30 cm). These sub-samples were combined and sieved to remove any material larger than 0.08 inches (2 mm) in diameter, and then sent to A&L Laboratories for S3C nutrient suite, total Kjeldahl nitrogen (TKN), and organic matter analysis. A control sample and a treatment sample were analyzed for particle size distribution.



**Figure 13. Soil sub-sample collection.**

### Rainfall Simulation

In 2006, rainfall simulation was conducted at the native site and at all of the test plots except for OR2. Average rainfall data from 2003 and 2004 at OR2 is presented alongside the 2006 data. In 2007, rainfall was conducted at all of the test plots (Figure 5). In 2007, standard frame installation protocols were not

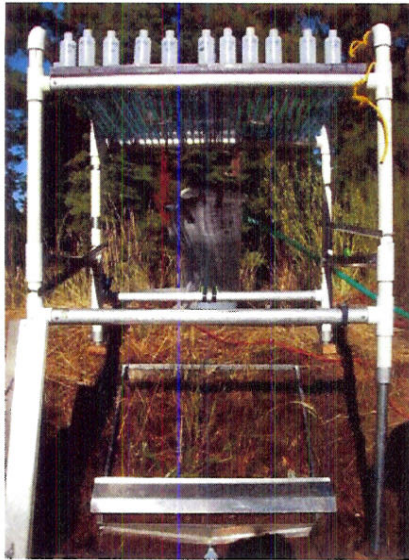
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<sup>5</sup> Claassen, V. P. and Hogan, M. P. Soil Nutrients Associated with Revegetation of Disturbed Sites in the Lake Tahoe Basin. *Restoration Ecology*. 2002 Jun; 10(2):195-203.

followed at all plots. Records could not be obtained detailing which plots had non-standard installations. Normally, the entire frame is hammered into the ground as one unit. During some installations, the frame was broken down into separate pieces and each piece was installed independently to form the original square configuration. This may have allowed some water to pass through the joining points of the frame pieces, which would decrease the amount of water captured in the trough.

The rainfall simulator “rains” on a square plot from a height of 3.3 feet (1 meter) (Figure 14 and Figure 15). The rate of rainfall is controlled, and runoff is collected from a trough at the bottom of a 6.5 square foot (0.6 square meter) frame that is pounded into the ground. The volume of water collected is measured and the volume of infiltration is calculated by subtracting the volume of runoff from the total volume of water applied to the plot. If runoff was not observed during the first 30 minutes, the simulation was stopped. The average steady state infiltration rate was calculated and is presented below. The collected runoff samples are then analyzed for the amount of sediment, which is presented as the average steady state sediment yield and referred as sediment yield in this report. The cone penetrometer was used to record the DTR surrounding the runoff frames before rainfall simulations. In 2004 and 2005, the DTR was read at 100 psi (689 kPa), which is very low. These values were not used in this report. The 2006 DTR pre-rainfall values that were taken at a maximum pressure of 250 psi (1,724 kPa) and the 2007 DTR values that were taken at 350 psi (2,413 kPa), are presented in this report. Soil moisture was also measured in each runoff frame prior to conducting the rainfall simulations. After rainfall simulation, at least three holes were dug with a trowel to determine the depth to wetting front, which shows how deeply the water infiltrated within the frame. In 2007, at least 9 holes were dug to measure the depth to wetting.

Different rainfall rates were applied to different plots depending on their propensity to runoff. The initial rainfall rate applied to the test plots was 2.8 inches/hour (72 mm/hr). If runoff was not observed, the rainfall rate was increased to 4.7 inches/hour (120 mm/hr) until runoff was observed or all the water was infiltrated. For plot OR1, the initial rainfall rate was 4.7 inches/hour (120 mm/hr). The rainfall rate of 2.8 inches/hour (71 mm/hr) is more than twice the intensity of the 20 year, 1 hour “design storm” for the local area.



**Figure 14. Rainfall simulator and frame.**



**Figure 15. Rainfall simulator set up at SK3.**

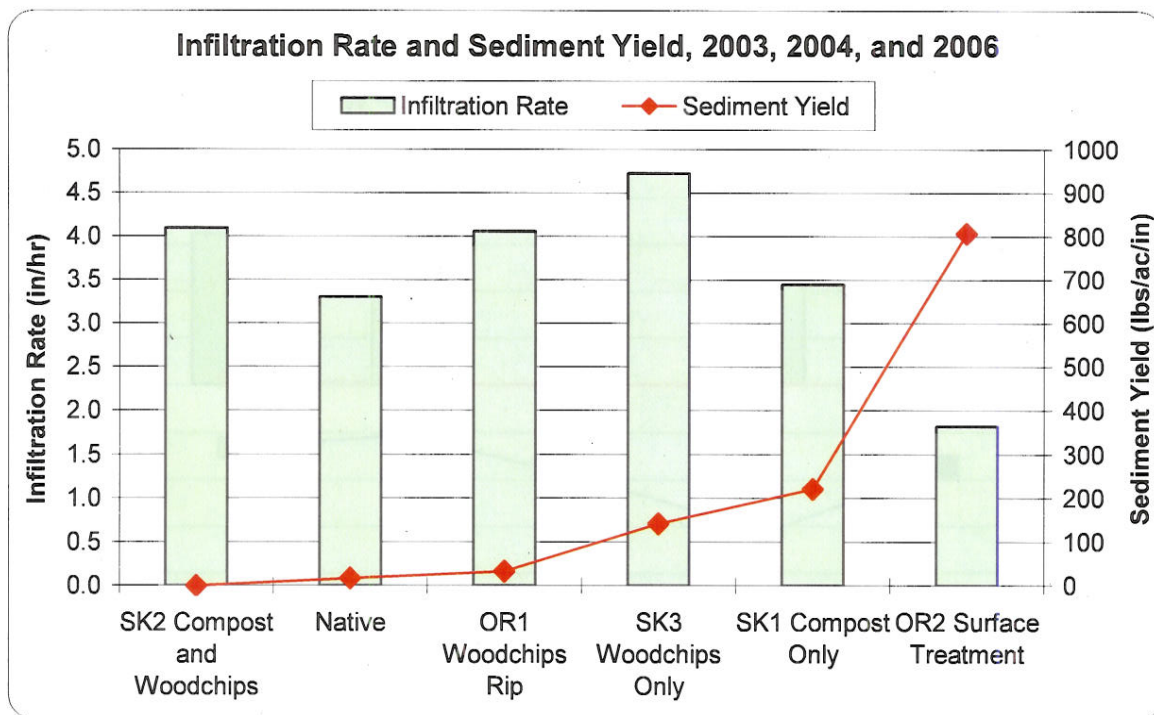
## **RESULTS/DISCUSSION**

### **Rainfall**

The average two year sediment yield at the surface treatment plot (no soil loosening), OR1, was 7.5 times higher than the average sediment yield at plots with soil loosening (OR2, SK1, SK2, and SK3) (Figure 16 and Figure 17). The average sediment yield for the plots with soil loosening was 54 lbs/acre/in (24 kg/ha/cm), while the average sediment yield for the plot without soil loosening was 404 lbs/acre/in (178 kg/ha/cm).

The average two year sediment yield at OR2, the plot with surface treatment, was 24 times higher than the average two year sediment yield for OR1 (surface treatment with subsequent ripping) and 6 times higher than the average two year sediment yields at the Snow King plots (Figure 16 and Figure 17). The average sediment yield at OR2 was 404 lbs/acre/in (178 kg/ha/cm), while the average sediment yield for OR1 was 17 lbs/acre/in (8 kg/ha/cm), and the average sediment yield for the Snow King plots was 54 lbs/acre/in (24 kg/ha/cm).

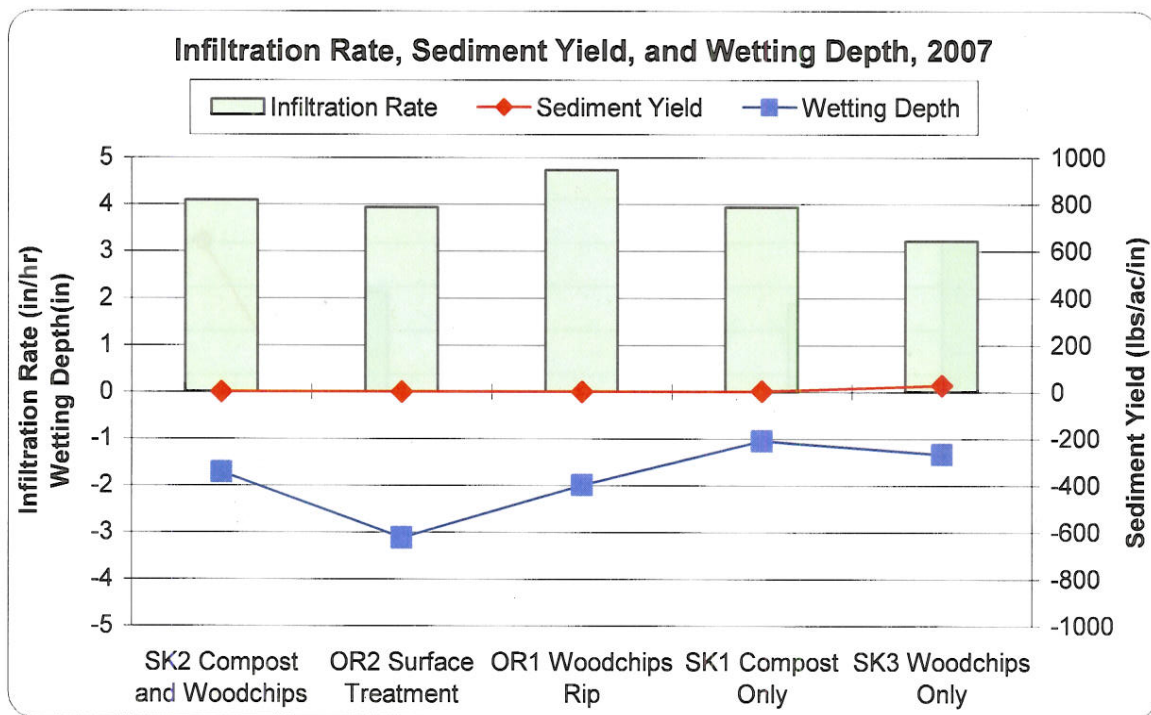
The average two year infiltration rate at OR2 was 1.5 times lower than the average two year infiltration rate for OR1 and 1.4 times lower than the average two year infiltration rate at the Snow King plots (Figure 16 and Figure 17). The infiltration rate at OR2 was 2.9 inches/hr (74 mm/hr), while the average infiltration rate for OR1 was 4.4 inches/hr (112 mm/hr) and the infiltration rate for the Snow King plots was 4.0 inches/hr (102 mm/hr).



**Figure 16. Infiltration Rate and Sediment Yield, 2003, 2004, and 2006. Data for OR2 is from 2003 and 2004. All other data is from 2006. OR2, the surface treatment plot, exhibited the highest sediment yield and the lowest infiltration rate when compared to the tilled, ripped, and native plots.**

When comparing the Snow King plots, SK2 (compost and woodchips plot), did not produce sediment in either 2006 or 2007, while both SK1 and SK3 produced sediment. The average two year sediment yield for the compost only plot, SK1, was 112 lbs/acre/in (49 kg/ha/cm) while the average sediment yield for the woodchips plot, SK3, was 85 lbs/acre/in (38 kg/ha/cm).

The plots that did not produce any sediment had wetting depths that were deeper than 1.7 inches (4.3 cm, Figure 17). OR2, which previously had a high sediment yield (404 lbs/acre/in or 178 kg/ha/cm) and low infiltration (2.9 inches/hr or 74 mm/hr), did not produce any sediment in 2007. The other plots that did not produce sediment were OR1 and SK2. The depth to wetting at OR2 was 3.1 inches (7.9 cm), while the depth to wetting at OR1 was 2 inches (5 cm), and 1.7 inches (4.3 cm) at SK2.



**Figure 17. Infiltration Rate, Sediment Yield, and Wetting Depth, 2007.** The plots that did not produce sediment had the deepest wetting depths. Only SK1 and SK3 produced sediment, in small quantities. The sediment scale is the same as Figure 16. DTR measurements were taken within the frame area.

Rainfall simulation results were inconsistent in 2007, which was most likely the result of either the non-standard rainfall frame installation, the increase in mulch cover, or the increase of plot performance over time (unlikely at the Old Reveg plots). Further discussion on individual plots is below.

The difference in plot performance between 2003, 2004, 2006, and 2007 at plot OR2 may be a result of:

- non-standard frame installation in 2007

The non-standard installation is described in the methods section above. It is possible that this installation method increased the infiltration rates and reduced the sediment yields. Excessive soil disturbance may have occurred by installing the frames one piece at a time, rather than as a whole unit. Excessive soil disturbance at the front edge of the frame can affect simulation results and sometimes results in preferential water flow paths between the inside front edge of the frame and the disturbed soil near the front edge. This flow path can carry water down the inside front edge of the frame, thereby avoiding the collection trough on the outside front edge of the frame (Figure 14). If the water is not collected, infiltration rates are artificially high and sediment yields are too low.

- deep and extensive mulch cover at OR1 and OR2 in 2007, compared to that in 2006 (Figure 19)

The mulch cover at OR2 was 78% in 2006 and increased to 100% in 2007. This increase in mulch is most likely a result of the greater than normal plant growth in 2006, which formed a dense mat of plant litter in 2007 (Figure 21). A high proportion of the mulch at OR2 in 2007 was likely comprised of this mat of plant litter from the previous growing season. The mulch depth in 2007 was 2.2 inches (5.6 cm), which is deeper than the initial application and was one of the two deepest depths measured at the Resort at Squaw Creek.

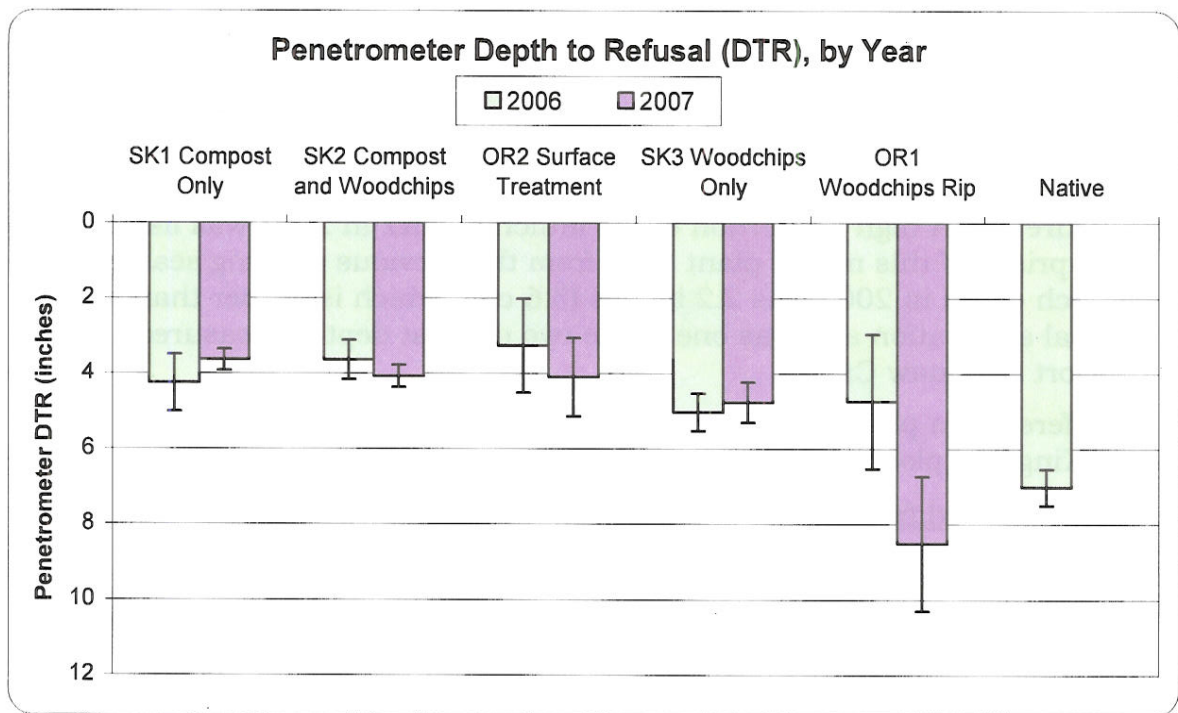
The difference in plot performance between 2003, 2004, 2006, and 2007 at the Snow King test plots could be a result of:

- non-standard frame installation (as discussed above)
- an increase in plot performance over time

Long term monitoring has shown that full treatment plots with soil loosening, organic amendments, fertilizer, native seed, and mulch perform better over time.

### **Soil Density**

OR1 and SK3, both plots that were amended with woodchips, had the deepest penetrometer DTRs (more than 4.9 inches), over a two year period (Figure 18). The average penetrometer DTRs at plots amended with woodchips only were 1.5 times deeper than the plot amended with compost only. The two year average DTR for OR1 was 6.6 inches (16.8 cm), and the average at SK3 was 4.9 inches (12.5 cm). In comparison, all the other treatment plots had DTRs less than 4 inches (10.2 cm). The lower soil density observed at plots OR1 and SK3 may be a result of the amendment type. Woodchips take several years to break down, thereby providing the soil with more varied structure over a longer time period than compost would provide.



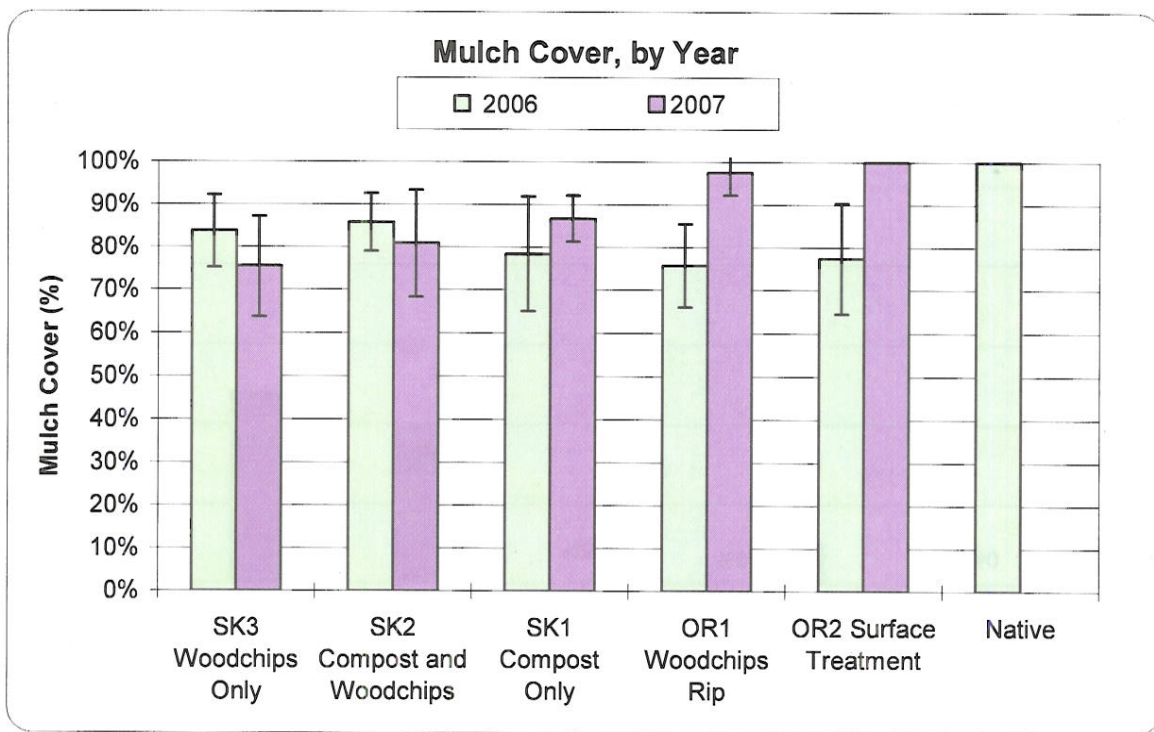
**Figure 18. Penetrometer Depth to Refusal (DTR), by Year.** The data is sorted by 2007 penetrometer depths. The native site was not monitored in 2007. OR1 and SK3 had the deepest average penetrometer DTRs over two years. Error bars denote one standard deviation above and below the mean.

## Cover

### Mulch Cover

The two sites that exhibited the greatest sediment reduction between 2006 and 2007, OR2 and SK1, exhibited increased cover by mulch between 2006 and 2007. The mulch cover at OR2 increased by 1.3 times from 78% to 100%, while the sediment yield decreased by 100% from 808 lbs/acre/in (357 kg/ha/cm) to zero. The mulch cover at SK1 increased by 1.1 times from 79% to 87%, while the sediment yield decreased by 99% from 222 lbs/acre/in to 2.3 lbs/acre/in. In other research, high mulch cover has been associated with sediment reduction.<sup>6</sup>

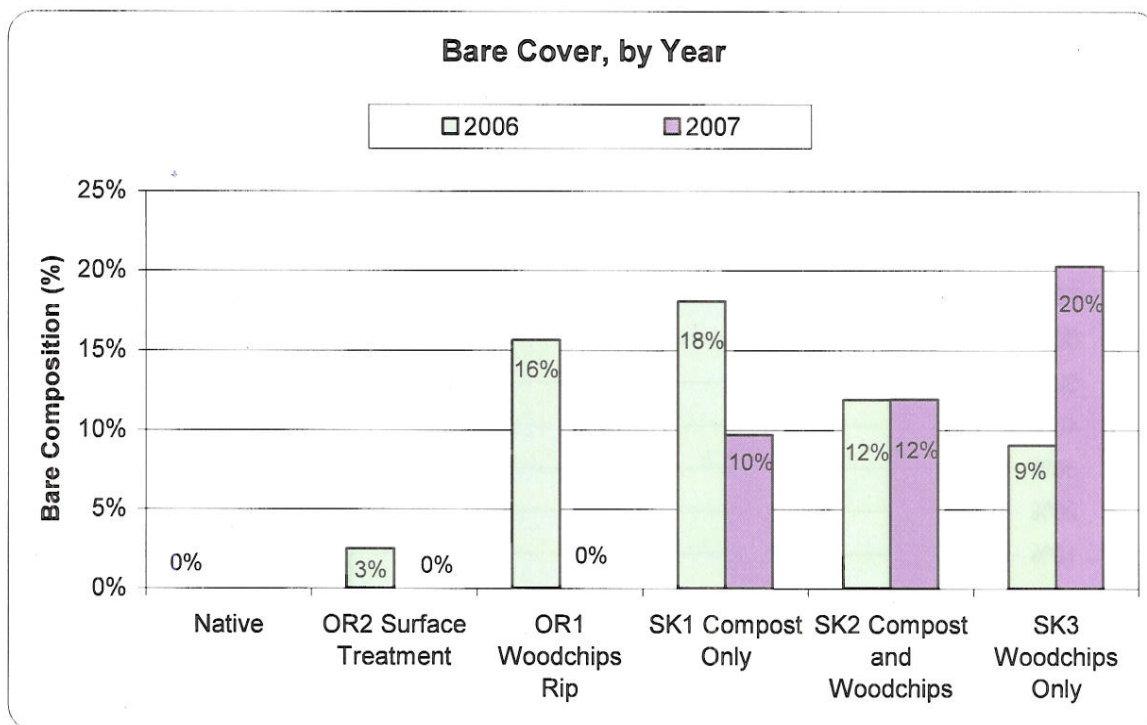
<sup>6</sup> Grismer, ME, Hogan, MP. 2004. Evaluation of revegetation/mulch erosion control using simulated rainfall in the Lake Tahoe basin: 1. Method Assessment. *Land Degrad. & Develop.* 13:573-578.



**Figure 19. Mulch Cover, by Year. The mulch cover increased at the OR plots.**

### Bare Soil

The proportion of bare soil decreased or remained the same at all test plots, with the exception of SK3 (woodchips only), where it increased by two times. In 2007, SK3 had 20% bare soil while the other test plots had less than 12% bare soil. Although all the test plots produced very little sediment in 2007, SK3 did produce the highest sediment yield of all the test plots (Figure 17). SK3 also had the lowest average plant cover over a 3 year period (see foliar plant cover section). Bare soil is more susceptible to erosion from rainfall than soil covered by mulch or plants. These two factors may have contributed to the higher sediment yield at SK3.



**Figure 20. Bare Cover, by Year.** In 2007, SK3 had the highest cover by bare soil and also produced the most sediment.

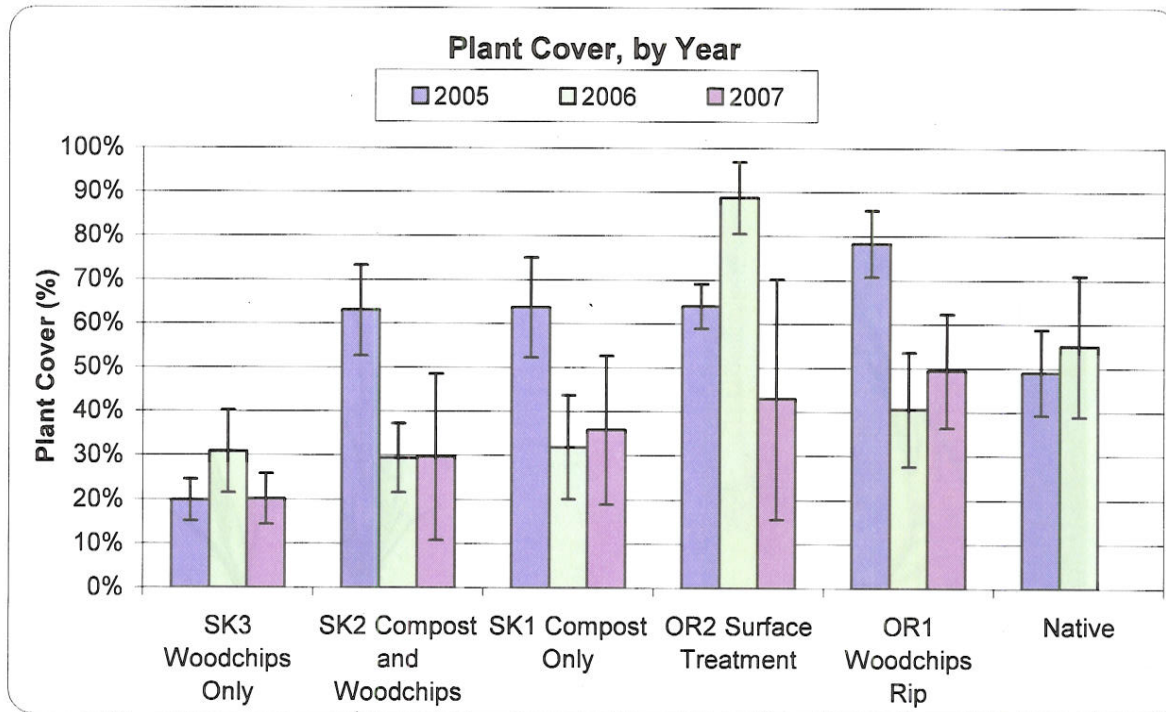
### Foliar Plant Cover

Plant cover at the Old Reveg plots was similar between the two treatments. The average plant cover at OR2 over a three year period was 65%, while the average cover at OR1 was 56%. In 2007, the standard deviation was very high at the OR2 plot, 27%. Therefore, more study will be needed to determine the plant cover trend at the Old Reveg plots.

The high plant cover at the Old Reveg plots most likely did not influence the infiltration capacity or sediment production exhibited by those plots. In 2006, the plant cover at OR2 was 88%; however, in the same year, it produce 808 lbs/acre/in (357 kg/ha/cm) of sediment and infiltrated only 1.82 inches/hour (46 mm/hour). In 2007, the plant cover was lower, 43%, but the infiltration rate was higher, 3.9 inches/hour (99 mm/hour), and no sediment was produced. This indicates that plant cover alone does not determine infiltration rates or sediment production.

At the Snow King plots, plots with compost (SK1 and SK2) exhibited the 1.7 times higher plant cover over a three year period when compared to the plot with woodchips only (SK3). The average three year plant cover at SK1 and SK2 was 44% and 41% respectively, while the average three year plant cover at SK3 was 24%. The more readily available nitrogen in compost compared to

woodchips most likely contributed to the greater plant growth at plots with compost.



**Figure 21. Plant Cover, by Year.** The data is sorted by 2007 plant cover. Plant cover at the native site was only measured in 2006. The OR plots had the highest average plant cover over three years. Of the Snow King plots, SK1, the plot with compost, had the highest average plant cover over three years, followed by the SK2, the plot with compost and woodchips.

### Plant Cover Composition

Perennial wheatgrasses, which are not native to the Tahoe area, composed 86 to 100% of the cover at the Old Revegetation plots between 2005 and 2007 (Figure 24). Although these perennial wheatgrasses were well-established and provided over 40% plant cover, they did not positively influence the infiltration capacity of the soil or aid in sediment reduction (Figure 16). Wheatgrass puts much of its energy into elongating its narrow stalk (Figure 22). The root system is not as extensive as that of the native perennial grass species selected for the Snow King plots. The foliar plant cover per stalk is greater for the native bunchgrasses than the introduced wheatgrasses due to the native species' denser layering of leaves (Figure 23). Native, perennial bunchgrasses are ideal seed selections and have extensive root systems that have been shown to

increase soil strength.<sup>7</sup> At some test areas, higher foliar cover by native perennial species was related to lower sediment yields.<sup>8</sup>



**Figure 22. Wheatgrass expends most of its energy to lengthening its tall and narrow stalk, which does not provide much foliar cover. Its roots do not penetrate as deeply as those of the native grasses.**



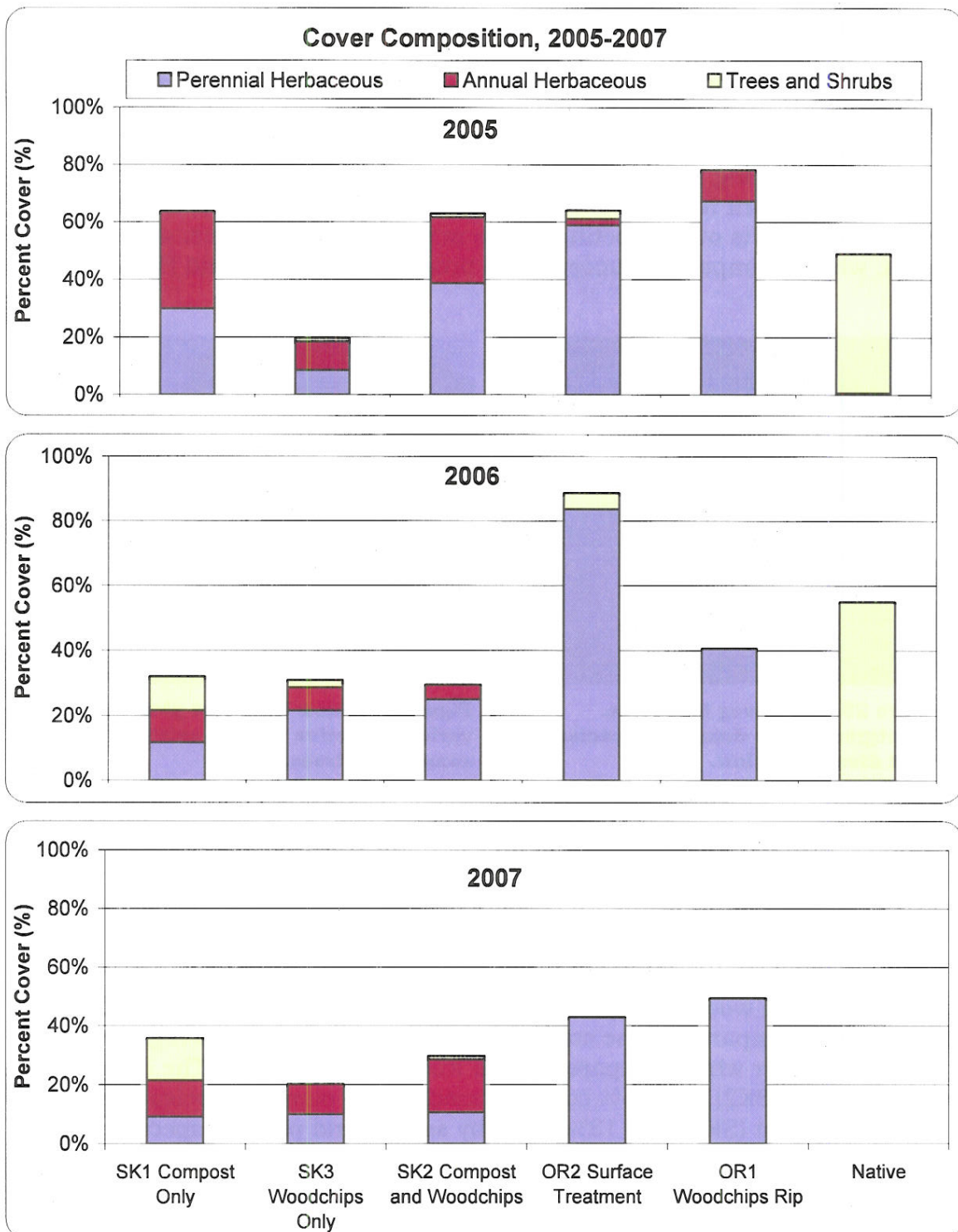
**Figure 23. Squirreltail has a deep root system and a high level of foliar cover compared to wheatgrass.**

Perennial species composition varied between 37% and 65% at the Snow King plots over the three year period. Average perennial plant cover for the three Snow King plots increased from 50% in 2005 to 65% in 2006. In 2007 cover by perennial plants decreased to 37%. These variations in perennial plant cover are most likely a result of the variation in average annual precipitation. Plant cover normally increases during a growing season following a higher than average water year (2006) and decreases following a lower than average water year (2007) The variation in perennial plant cover at the Snow King plots did not directly affect the infiltration capacity or the sediment production at those sites.

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<sup>7</sup> Tengbeh, G.T. 1993. The Effect of Grass Roots on Shear Strength Variations with Moisture Content. *Soil Technology*. Vol. 6. pp. 287-295.

<sup>8</sup>Monitoring and Assessment of Erosion Control Treatments in and around the Lake Tahoe Basin, Northstar Lookout Mountain Site Report, 2006 unpublished.



**Figure 24. Cover Composition, 2005-2007. Native data was not collected in 2007. Cover composition was consistent at the OR plots. At the SK plots, the percent of perennial cover increased between 2005 and 2006, and decreased between 2006 and 2007.**

Trees and shrubs are the dominant species at the native site, which is in the late seral stage of plant development. Tree and shrub species are beginning to establish at the Snow King plots, but not at the Old Reveg plots. The compost only plot, SK1, has the greatest cover by woody species. This may be in part due to its location near to a wooded area. The only shrub species to establish at the OR plots 16 years after treatment is thimbleberry (*Rubus parviflorus*), which is encroaching from the adjacent area. Establishment of tree and shrub species is important in moving to the next successional level. At the Old Reveg plots, wheatgrass is outcompeting native perennial grasses, tree, and shrub species, which is impeding successional progress (Figure 25 and Figure 26).



**Figure 25. Old Reveg test plots. Wheatgrass is the dominant species. Plant diversity is low.**

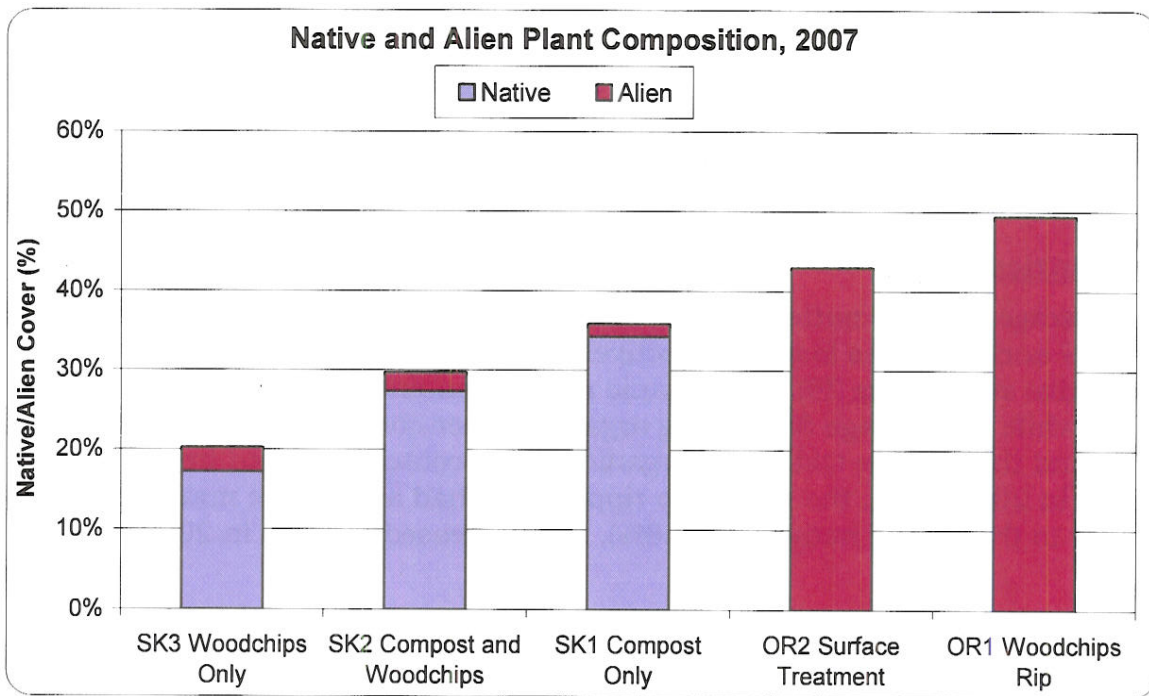


**Figure 26. Snow King test plots. A variety of native species exist including some small trees.**

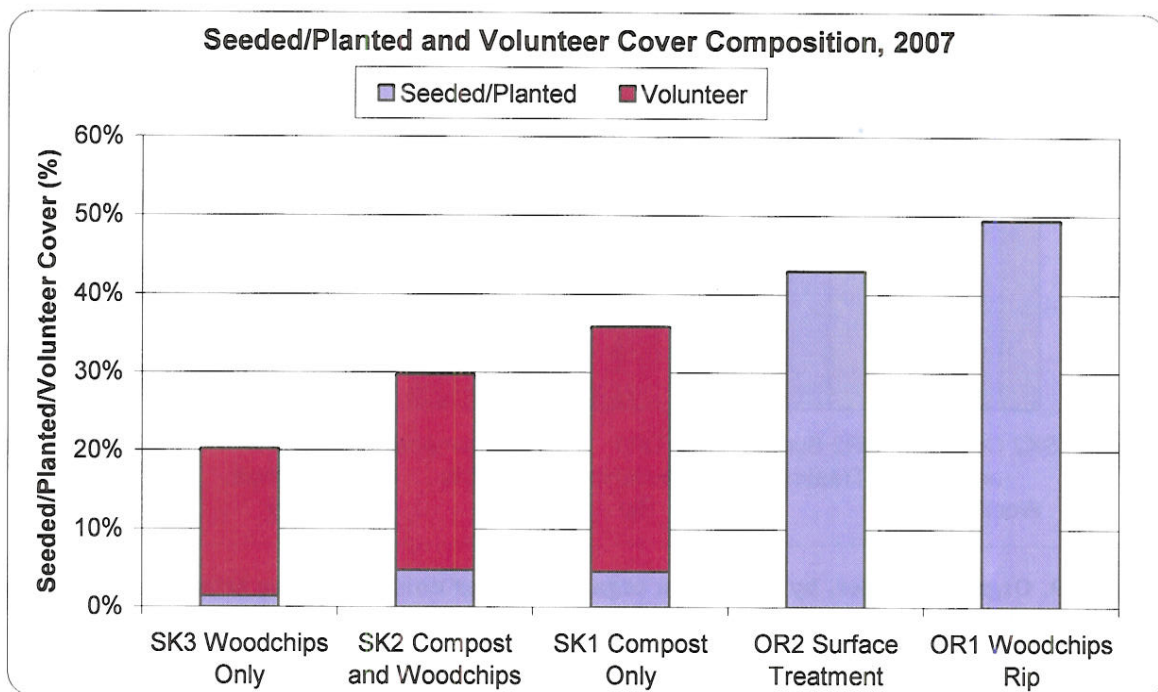
In 2007, native plants dominated at all the Snow King plots, while alien plants dominated at the Old Reveg plots (Figure 27). Native plants composed 85% or more of the foliar cover at the SK plots, while alien plants composed 100% of the cover at the OR plots. There was 91% higher cover by native plants at the Snow King plots compared to OR2, the surface treatment plot.

The compost and woodchips plot, SK2, had similar percent of seeded/planted species when compared to the compost only plot, and 2.3 times higher seeded and planted cover when compared to the woodchips only plot. The compost and woodchips plot (SK2) had 16% cover by seeded and planted species, the compost only plot (SK1) had 13% cover by seeded and planted species, while the woodchips only plot (SK3) had 7% cover by seeded and planted species.

Volunteer species, a majority of which were native, were able to establish at the Snow King Plots and composed 84 to 93% of the plant cover (Figure 27 and Figure 28). This shows that the plot environment was similar enough to native areas for establishment of volunteer native species.



**Figure 27. Native and Alien Plant Composition, 2007. Native plants dominated at all the Snow King plots, while alien plants dominated at the Old Reveg plots.**

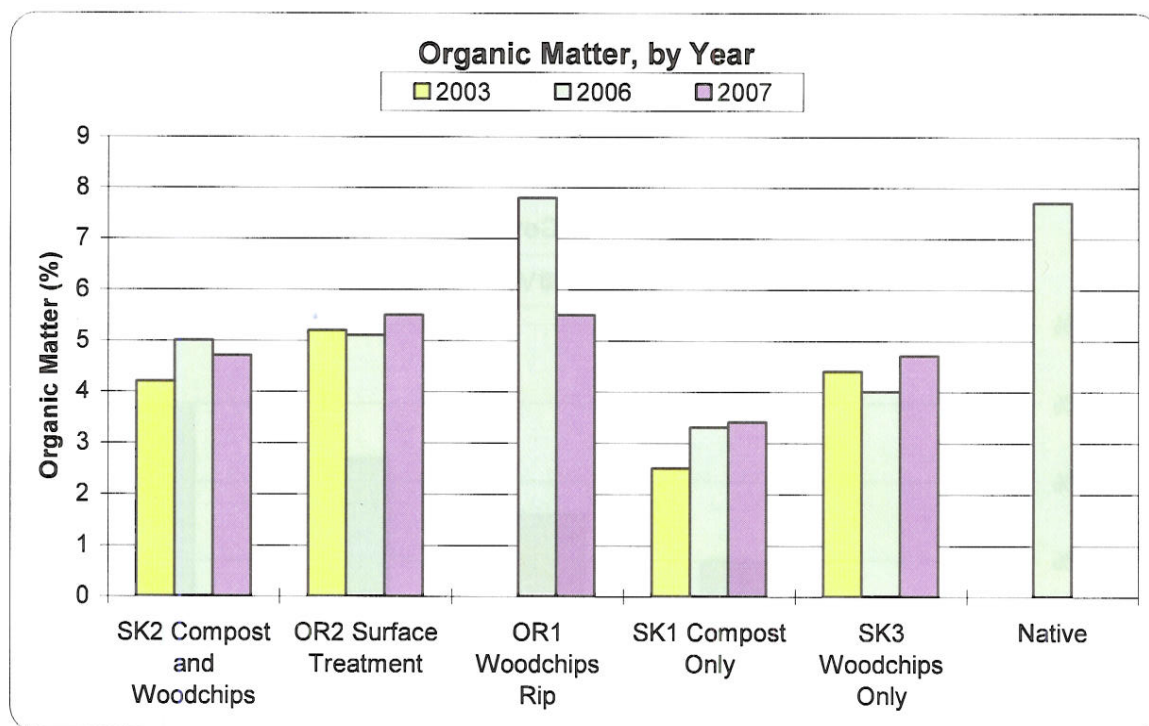


**Figure 28. Seeded/Planted and Volunteer Cover Composition, 2007. Seeded species dominated at the Old Reveg plots, while volunteer species dominated at the Snow King plots.**

When compared to squirreltail and mountain brome, blue wild rye had the highest cover by ocular estimate during both 2006 (5 to 25%), a high water year, and 2007, a low water year (5 to 10%, Appendix A). Mountain brome decreased in cover from 10 to 20% in 2006 to trace amounts in 2007. Squirreltail decreased from 10 to 20% in 2006 to 2 to 10% in 2007.

### **Soil Nutrients**

The average organic matter content at the Snow King plots and Old Reveg plots was 1.9 and 1.3 times lower, respectively, than the organic matter content at the native site (Figure 29). The organic matter content at the native site was 7.7%, while the average Snow King organic matter contents ranged from 3.0 to 4.6% and the average Old Reveg organic matter contents ranged from 5.3 to 6.7%. In 2006, OR1, the woodchip ripped plot, had an organic matter content similar to that of the native site (7.8%), but decreased to 5.2% in 2007.



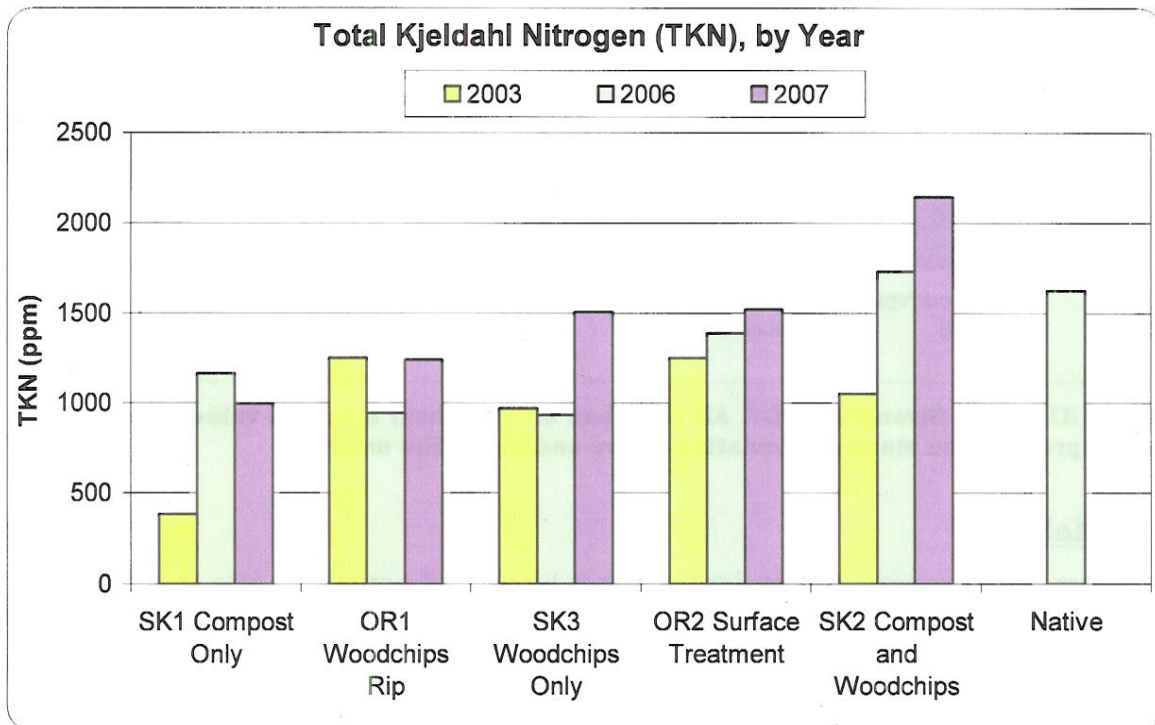
**Figure 29. Organic Matter, by Year.** The organic matter content at the treatment plots did not reached native levels.

The average TKN level at the Snow King and Old Reveg plots was 1.3 times lower than the TKN level of the native site (Figure 30). The average TKN level at the Snow Kings plots was 1,390 ppm, the average TKN at the Old Reveg plots was 1,240 ppm, and TKN at the native site was 1,627 ppm.

When comparing the Snow Kings plots, plot SK1 (compost only), had an organic matter content that was 1.5 times lower than at SK2 and SK3 and a TKN level that was 1.6 times lower than the other Snow King plots. The three year average organic matter content was 3.3% at SK1 and the average TKN was 850 ppm (Figure 29 and Figure 30). The average organic matter for the other plots ranged from 4.4 to 6.7%, while TKN ranged from 1,093 to 1,643 ppm.

When comparing the Old Revegetation plots, the organic matter at OR2 (surface treatment) was 1.3 times lower than at OR1 (woodchips rip). The organic matter content at OR2 was 5.3%, while the organic matter content at OR1 was 6.7%.

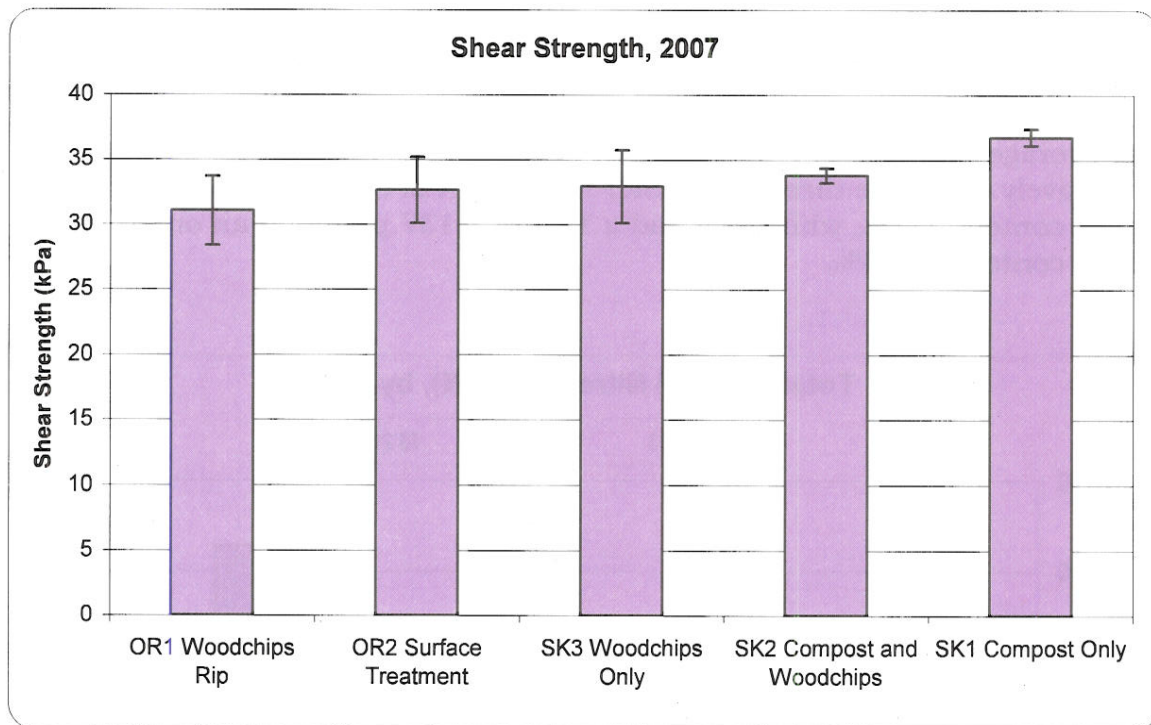
The total Kjeldahl nitrogen (TKN) and organic matter at the SK2 plot (compost and woodchips), were 1.7 and 1.3 times higher, respectively, than the TKN and organic matter at SK1 and SK3 (compost only and woodchips only). The three-year average TKN and organic matter for SK2 were 1,643 ppm and 4.6%, respectively. Over the three years, SK1 had a TKN of 849 ppm and an organic matter content of 3%, while SK3 had a TKN of 1,137 ppm and an organic matter content of 4.4%.



**Figure 30. Total Kjeldahl Nitrogen (TKN), by Year. The TKN at SK2 exceeded native levels in 2007.**

### Shear Strength

The shear strength values were similarly high across all treatment types and ranged from 31 to 37 kPa (Figure 31). The high shear strength values recorded may have been due to different soil characteristics at different plots. At OR2, the strength may have been a result of the high soil density, while at OR1 the strength may have been a result of denser plant roots. At the SK plots and at OR1, strength may have been derived from woody organic material and the bonds formed by the soil fauna and microbes in the breakdown of the organic material.



**Figure 31. Shear Strength, 2007. All plots had similar shear strength values. The error bars represent one standard deviation above and below the mean.**

### Soil Moisture

Soil temperature and soil moisture affect biological activity in the soil. This activity is maximized at certain moisture levels with considerable decreases in biological activity above or below those levels.<sup>9, 10</sup>

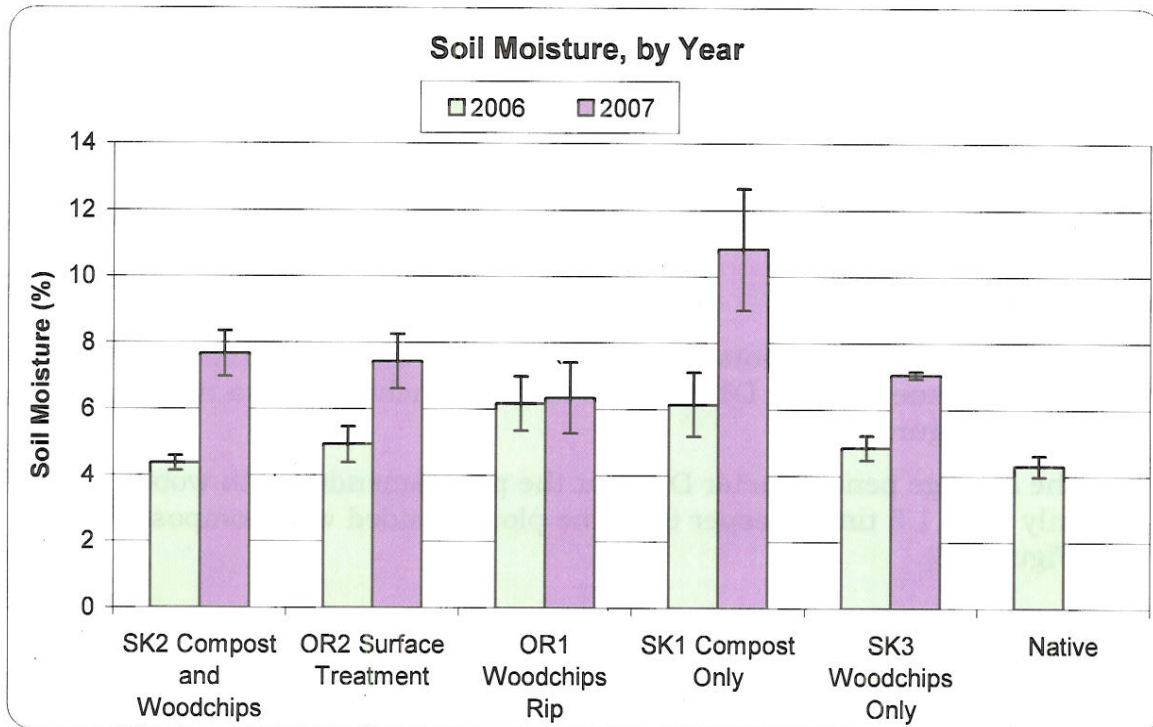
In 2006, no consistent relationship was observed between soil moisture and treatment type. The soil moisture in August was between 4% and 6% for all

<sup>9</sup> Paul E. A. and F.E. Clark. 1989. Soil Microbiology and Biochemistry. San Diego: Academic Press

<sup>10</sup> Allen, M.F. 1992. Mycorrhizal Functioning. NY: Chapman and Hall.

treatments, which is a normal soil moisture level in local volcanic soils with high solar exposure (Figure 32).

In 2007, the two plots amended with compost, SK1 and SK2, had the highest soil moisture. The 2007 soil moisture was recorded in July and ranged between 6.4 and 10.8%. The addition of compost may have increased the water holding capacity of the soil, as this was not observed at the other plots. This trend was not observed in 2006, when the moisture was measured later in the season.



**Figure 32. Soil Moisture, by Year.** Error bars denote one standard deviation above and below the mean.

## CONCLUSIONS

### Infiltration

- The average two year sediment yield at the surface treatment plot (no soil loosening), OR1, was 7.5 times higher than the average sediment yield at plots with soil loosening (OR2, SK1, SK2, and SK3).
- The average two year sediment yield at OR2, the plot with surface treatment, was 24 times higher than the average two year sediment yield for OR1 (surface treatment with subsequent ripping) and 6 times higher than the average two year sediment yields at the Snow King plots (Figure 16 and Figure 17).

- The average two year infiltration rate at OR2, the plot without soil loosening, was 1.5 times lower than the average two year infiltration rate for OR1 (with soil loosening) and 1.4 times lower than the average two year infiltration rate at the Snow King plots, all of which had soil loosening (Figure 16 and Figure 17).
- When comparing Snow King plots to each other, SK2 (compost and woodchips plot), did not produce sediment in either 2006 or 2007, while both SK1 and SK3 produced sediment.
- The plots that did not produce any sediment had wetting depths that were deeper than 1.7 inches (4.3 cm) (Figure 17).
- Rainfall simulation results were inconsistent in 2007, which were most likely the result of either the non-standard rainfall frame installation, the increase in mulch cover, or the increase of plot performance over time (unlikely at the Old Reveg plots).

### **Soil Density**

- OR1 and SK3, both plots that were amended with woodchips, had the deepest penetrometer DTRs (more than 4.9 inches), over a two year period (Figure 18).
- The average penetrometer DTRs at the plots amended with woodchips only were 1.5 times deeper than the plot amended with compost only (Figure 18).

### **Mulch Cover**

- The mulch cover at OR2 increased by 1.3 times from 78% to 100%, while the sediment yield decreased by 100% from 808 lbs/acre/in (357 kg/ha/cm) to zero.
- The mulch cover at SK1 increased by 1.1 times from 79% to 87%, while the sediment yield decreased by 99% from 222 lbs/acre/in to 2.3 lbs/acre/in.

### **Bare Soil**

- The proportion of bare soil decreased or remained the same at all test plots, with the exception of SK3 (woodchips only), where it increased by two times.

### **Foliar Plant Cover**

- Plant cover at the Old Reveg plots was similar between the two treatments.
- The high plant cover at the Old Reveg plots most likely did not influence the infiltration capacity or sediment production exhibited by those plots.
- At the Snow King plots, plots with compost (SK1 and SK2) exhibited the 1.7 times higher plant cover over a three year period when compared to the plot with woodchips only (SK3).

### **Plant Cover Composition**

- Perennial wheatgrasses, which are not native to the Tahoe area, composed 86 to 100% of the cover at the Old Reveg plots between 2005 and 2007 (Figure 24).
- At the Old Reveg plots, wheatgrass is outcompeting native perennial grasses, tree, and shrub species, which is impeding successional progress (Figure 25 and Figure 26).
- Perennial species composition varied between 37% and 65% at the Snow King plots over the three year period
- Trees and shrubs are the dominant species at the native site, which is in the late seral stage of plant development. Tree and shrub species are beginning to establish at the Snow King plots, but not at the Old Reveg plots.
- In 2007, native plants dominated at all the Snow King plots, while alien plants dominated at the Old Reveg plots (Figure 27).
- Volunteer species, a majority of which were native, were able to establish at the Snow King Plots and composed 84 to 93% of the plant cover (Figure 27 and Figure 28).
- When compared to squirreltail and mountain brome, blue wild rye had the highest cover by ocular estimate during both 2006 (5 to 25%), a high water year, and 2007, a low water year (5 to 10%) (Appendix A).
- Mountain brome decreased in cover from 10 to 20% in 2006 to trace amounts in 2007.
- Squirreltail decreased from 10 to 20% in 2006 to 2 to 10% in 2007.

### **Soil Nutrients**

- The organic matter content at the Snow King plots and Old Reveg plots was 1.9 and 1.3 times lower, respectively, than the organic matter content at the native site (Figure 29).

- The average TKN level at the Snow King and Old Reveg plots was 1.3 times lower than the TKN level of the native site.
- When comparing the Snow Kings plots, plot SK1 (compost only), had an organic matter content that was 1.5 times lower than at SK2 and SK3 and a TKN level that was 1.6 times lower than the other Snow King plots.
- When comparing the Old Reveg plots, the organic matter at OR2 (surface treatment) was 1.3 times lower than at OR1 (woodchips rip).

### **Shear Strength**

- The shear strength values were similarly high across all treatment types and ranged from 31 to 37 kPa (Figure 31).

### **Soil Moisture**

- In 2006, no consistent relationship was observed between soil moisture and treatment type.
- In 2007, the two plots amended with compost, SK1 and SK2, had the highest soil moisture.

## **RECOMMENDATIONS**

For sites with rocky soil, from volcanic parent material, with a slope of approximately 19 degrees at an elevation of about 6,900 feet:

Ripping: 12 inches (30 cm)

Amendment: 5 inches (12.7 cm) of a 50/50 combination of compost and woodchips

Biosol: 1,500 lbs/acre (1,784 kg/ha)

Seed: 100 lbs/acre (112 kg/ha) with the following composition is recommended:

mountain brome: 25%

squirreltail: 32.5%

blue wild rye: 32.5%

native forbs and shrubs: 10%

Mulch: 2 inches (5 cm) pine needles mulch with 99% cover

### **Full treatment (Snow King Plots) versus Surface Treatment (OR2)**

The tested full treatments, which includes soil loosening to 12 inches, 3 inches of organic soil amendment application (50/50 compost/woodchips mix), organic fertilizer addition (at least 1,500 lbs/ac or 1,684 kg/ha), native seed

application, and pine needle mulch at a 2 inch depth, is recommended for the following reasons over surface treatment.

Full treatment plots exhibited:

- sediment yields that were 7.5 times lower than plots without soil loosening
- infiltration rates that were approximately 1.5 times higher than at plots without soil loosening
- establishment of young trees and shrubs, which were outcompeted by the non-native grasses at the surface treatment plot
- 91% higher plant cover by native species
- the ability to host volunteer (mostly native) species, which composed 84 to 93% of the plant cover

#### **Surface Treatment with Subsequent Woodchip Ripping (OR1) versus Surface Treatment (OR2)**

Surface treatment with subsequent woodchip ripping is recommended over surface treatment for the following reasons. The surface treatment plot with subsequent ripping exhibited:

- a sediment yield that was 24 times lower than the sediment yield at the surface treatment plot
- an infiltration rate that was 1.5 times higher than the infiltration rate at the surface treatment plot
- organic matter content that was 1.3 times higher than the organic matter content at the surface treatment plot

#### **Soil Loosening versus No Soil Loosening**

Soil loosening is recommended for the following reasons. Plots with soil loosening exhibited:

- sediment yields that were 7.5 times lower than at plots without soil loosening
- infiltration rates that were 1.5 times higher than at plots without soil loosening

### **Amendment Types (Compost versus Woodchips versus 50/50 Combination)**

The combination of compost and woodchips, applied to a depth of 5 inches (12.7 cm) versus the 3 inches (7.6 cm) tested at these plots, as part of a full soil treatment, is recommended above either amendment alone for the following reasons.

Compost and woodchip plot exhibited:

- no sediment production in 2006 and 2007, compared to 112 lbs/acre/in at SK1 and 85 lbs/acre/in at SK3.
- a penetrometer depth that was slightly shallower than the woodchip only plot (a deeper total depth of the 50/50 mix is recommended (5 inches versus 3 inches) to take advantage of the ability of woodchips to aid in maintaining lower soil density)
- plant cover that was 1.7 times higher than the plant cover at the plot with woodchips only and similar to the plot with compost only
- total Kjeldahl nitrogen (TKN) and organic matter levels that were 1.7 and 1.3 times higher, respectively, than TKN and organic matter at SK1 (compost only) and SK3 (woodchips only).
- similar percent of seeded and planted species when compared to the compost only plot
- a seeded and planted species cover that was 2.3 times higher when compared to the woodchips only plot

### **Biosol**

Biosol application is recommended at 2,000 lbs/acre (2,241 kg/ha) versus the 1,500 lbs/acre (1,784 kg/ha) tested at these plots for the following reason:

- Nutrient levels did not reach native levels with the 1,500 lbs/acre (1,784 kg/ha) application

### **Seed**

Seed, applied at 100 lbs/acre (112 kg/ha) with the following composition is recommended:

mountain brome: 25%  
squirreltail: 32.5%  
blue wild rye: 32.5%  
native shrubs: 10%

For the following reasons:

- squirreltail and blue wild rye were present in greater quantities than mountain brome (Appendix A), so quantities were increased slightly over tested rates

### **Mulch**

Pine needle mulch, applied to a depth of 2 inches (5 cm) is recommended, over the 1 inch (2.5 cm) tested for the following reasons:

- when mulch cover at OR2 increased by 1.3 times from 78% to 100%, the sediment yield decreased by 100% from 808 lbs/acre/in (357 kg/ha/cm) to zero.
- when mulch cover at SK1 increased by 1.1 times from 79% to 87%, the sediment yield decreased by 99% from 222 lbs/acre/in to 2.3 lbs/acre/in.
- Several years following treatment, some areas had mulch cover of less than 90%, which may increase the likelihood of sediment production.

## Appendix A

### Species List for the Resort at Squaw Creek Snow King, Old Reveg, and Native sites, including ocular estimates of cover, 2006

Lifeform	Family	Scientific name	Common name	Annual/ Perennial	Native/ Alien	Noxious/ Invasive	Phenology	SK1 Ocular Cover (%)	SK2 Ocular Cover (%)	SK 3 Ocular Cover (%)	OR1 Ocular Cover (%)	OR2 Ocular Cover (%)	Native Ocular Cover (%)
Forb	Asteraceae	Achillea millefolium	yarrow	Perennial	Native		Veg.	< 5	< 5	5	T		
Forb	Asteraceae	Antennaria rosea	pussy toes	Perennial	Native		Flower						
Forb	Brassicaceae	Arabis holboellii	Holboell's rockcress	Perennial	Native		Seed		T				
Forb	Asteraceae	Aster ascendens	long-leaved aster	Perennial	Native		Flower		T	T			
Forb	Brassicaceae	Capsella bursa-pastoris	shepherd's purse	Annual	Alien		Seed						
Forb	Asteraceae	Chaenactis douglasii	Douglas pincushion	Perennial	Native		Veg.	T					
Forb	Asteraceae	Cirsium andersonii	Anderson's thistle	Perennial	Native		Flower	T	T		T	T	
Forb	Polemoniaceae	Collomia tinctoria	staining collomia	Annual	Native		Flower			T	T		
Forb	Boraginaceae	Cryptantha ambigua	Wilke's cryptantha	Annual	Native		Seed	T	T				
Forb	Brassicaceae	Descurainia sophia	herb Sophia	Annual	Alien	Invasive	Seed						
Forb	Polygonaceae	Eriogonum nudum	nude buckwheat	Perennial	Native		Veg.			T	T		
Forb	Polygonaceae	Eriogonum umbellatum	sulfur flower	Perennial	Native		Veg.	T	5 - 10	5 - 10			
Forb	Geraniaceae	Erodium cicutarium	red stem storksbill	Annual	Alien	Invasive	Seed						
Forb	Onagraceae	Gayophytum diffusum	prairie smoke	Perennial	Native		Flower	5 - 10	15 - 20	5 - 10			
Forb	Asteraceae	Hieracium albiflorum	Hawkweed	Perennial	Native		Flower	T					
Forb	Asteraceae	Lactuca serriola	devil's lettuce	Annual	Alien	Invasive	Veg.						
Forb	Fabaceae	Lathyrus latifolius	sweet pea	Perennial	Alien		Flower			T			
Forb	Brassicaceae	Lepidium campestre	English pepperweed	Annual	Alien		Seed						
Forb	Asteraceae	Leucanthemum vulgare	ox-eye daisy	Perennial	Alien	Invasive	Flower	< 5	< 5	< 5	T		
Forb	Polemoniaceae	Linanthus harknessii	Harken's linanthus	Annual	Native		Dry	T					
Forb	Fabaceae	Lotus purshianus	Spanish lotus	Perennial	Native		Flower						
Forb	Fabaceae	Lupinus argenteus	silver lupine	Perennial	Native		Seed						
Forb	Fabaceae	Lupinus lepidus (culbertsonii)	Culbertson's lupine	Perennial	Native		Seed	< 5	< 5				
Forb	Asteraceae	Madia glomerata	mountain tarweed	Annual	Native		Flower	< 5	< 5	5 - 10	T		
Forb	Lamiaceae	Monardella odoratissima	mountain monardella	Perennial	Native		Flower		T		T		
Forb	Onagraceae	Oenothera sp.	evening primrose	Perennial	Native		Veg.						
Forb	Scrophulariaceae	Pedicularis semibarbata	lousewort	Perennial	Native		Veg.						T
Forb	Scrophulariaceae	Penstemon laevis	gay penstemon	Perennial	Native		Flower		T				
Forb	Hydrophyllaceae	Phacelia hastata	silverleaf phacelia	Perennial	Native		Veg.						
Forb	Polemoniaceae	Phlox gracilis	slender phlox	Annual	Native		Dry						

Lifeform	Family	Scientific name	Common name	Annual/ Perennial	Native/ Alien	Noxious/ Invasive	Phenology	SK1 Ocular Cover (%)	SK2 Ocular Cover (%)	SK 3 Ocular Cover (%)	OR1 Ocular Cover (%)	OR2 Ocular Cover (%)	Native Ocular Cover (%)
Forb	Polygonaceae	Polygonum douglasii	Douglas knotweed	Annual	Native		Flower		T	< 5			
Forb	Ericaceae	Pyrola picta	wintergreen	Perennial	Native		Veg.						T
Forb	Brassicaceae	Sisymbrium altissimum	tumble mustard	Annual	Alien		Seed						
Forb	Apiaceae	Sphenosciadium capitellatum	ranger's buttons	Perennial	Native		Flower				T	T	
Forb	Asteraceae	Taraxacum officinale	dandelion	Annual	Alien	Invasive	Veg.	T					
Forb	Asteraceae	Tragopogon dubius	false salisfly	Annual	Alien		Seed		T				
Forb	Fabaceae	Trifolium repens	white clover	Perennial	Alien		Veg.	T					
Forb	Scrophulariaceae	Verbascum thapsus	mullen	Annual	Native	Invasive	Flower						
Graminoid	Poaceae	Achnatherum nelsonii	Nelson's needlegrass	Perennial	Native		Seed			5			
Graminoid	Poaceae	Achnatherum occidentale	Western needlegrass	Perennial	Native		Seed	< 5	10				
Graminoid	Poaceae	Agropyron dasystachyum	pubescent wheatgrass	Perennial	Alien		Seed				20 - 30	75	
Graminoid	Poaceae	Agropyron intermedium	intermediate wheatgrass	Perennial	Alien		Seed	30	40	30 - 40	50 - 60	30	
Graminoid	Poaceae	Bromus carinatus	mountain brome	Perennial	Native		seed	10	15 - 20	10			
Graminoid	Poaceae	Bromus tectorum	cheatgrass	Annual	Alien	Invasive	Seed						
Graminoid	Poaceae	Dactylis glomerata	orchard grass	Perennial	Alien	Invasive	Veg.	10	10				
Graminoid	Poaceae	Deschampsia elongata	elongated hairgrass	Perennial	Native		Seed						
Graminoid	Poaceae	Elymus elymoides	squirreltail grass	Perennial	Native		Flower	10	20	10 - 15			
Graminoid	Poaceae	Elymus glaucus	blue wildrye	Perennial	Native		Seed	5 - 10	20 - 25	25			
Graminoid	Poaceae	Hordeum vulgare	barley	Annual	Alien		Flower						
Graminoid	Poaceae	Poa secunda	Secund's bluegrass	Perennial	Native		Seed	< 5					
Shrub	Ericaceae	Arctostaphylos nevadensis	pinemat manzanita	Perennial	Native		Veg.	< 5					70
Shrub	Ranunculaceae	Ceanothus cordulatus	buckthorne	Perennial	Native		Veg.	T					
Shrub	Rosaceae	Rubus parviflorus	thimbleberry	Perennial	Native		Veg.					5 - 10	
Shrub	Caprifoliaceae	Symphoricarpos mollis	trailing snowberry	Perennial	Native		Veg.					T	
Tree	Pinaceae	Abies concolor	white fir	Perennial	Native		sapling	20	T	T			10 - 20
Tree	Pinaceae	Pinus jefferyi	Jeffrey pine	Perennial	Native		Veg.	T					

**Species List for the Resort at Squaw Creek Snow King, Old Reveg, and Native sites including ocular estimates of cover, 2007**

Lifeform	Family	Scientific name	Common name	Annual/ Perennial	Native/ Alien	Noxious/ Invasive	In seed mix?	% in seed mix	SK1 Ocular Cover (%)	SK2 Ocular Cover (%)	SK3 Ocular Cover (%)	OR1 Ocular Cover (%)	OR2 Ocular Cover (%)	Native Ocular Cover (%)
Forb	Asteraceae	Achillea millefolium	yarrow	Perennial	Native				T	<5	<5			
Forb	Asteraceae	Chaenactis douglasii	Douglas pincushion	Perennial	Native				T	T	T			
Forb	Asteraceae	Cirsium andersonii	Anderson's thistle	Perennial	Native				T	T	T			
Forb	Polemoniaceae	Collomia tinctoria	staining collomia	Annual	Native						T	T		
Forb	Boraginaceae	Cryptantha ambigua	Wilke's cryptantha	Annual	Native					T	T			
Forb	Polygonaceae	Eriogonum nudum	nude buckwheat	Perennial	Native				T	T		T		
Forb	Polygonaceae	Eriogonum umbellatum	sulfur flower	Perennial	Native				<5	5-10	5-10			
Forb	Geraniaceae	Erodium cicutarium	red stem storksbill	Annual	Alien	Invasive								
Forb	Onagraceae	Gayophytum diffusum	prairie smoke	Perennial	Native				10	15-20	10-15			
Forb	Asteraceae	Leucanthemum vulgare	ox-eye daisy	Perennial	Alien	Invasive			5	<5	<5	T		
Forb	Fabaceae	Lupinus lepidus (culbertsonii)	Culbertson's lupine	Perennial	Native				T	T	T			
Forb	Asteraceae	Madia glomerata	mountain tarweed	Annual	Native				T	5	5-10	T		
Forb	Lamiaceae	Monardella odoratissima	mountain monardella	Perennial	Native					T	T	T		
Forb	Scrophulariaceae	Pedicularis semibarbata	lousewort	Perennial	Native									T
Forb	Scrophulariaceae	Penstemon laevis	gay penstemon	Perennial	Native					T				
Forb	Hydrophyllaceae	Phacelia hastata	silverleaf phacelia	Perennial	Native				T					
Forb	Polygonaceae	Polygonum douglasii	Douglas knotweed	Annual	Native					T	<5			
Forb	Ericaceae	Pyrrola picta	wintergreen	Perennial	Native									
Forb	Apiaceae	Sphenosciadium capitellatum	ranger's buttons	Perennial	Native							T	T	
Graminoid	Poaceae	Achnatherum occidentale	Western needlegrass	Perennial	Native				T	<5	<5			
Graminoid	Poaceae	Agropyron dasytachyum/Elymus lanceolatus	pubescent wheatgrass	Perennial	Alien		RSC	unknown				20	20	
Graminoid	Poaceae	Agropyron intermedium /Elytrigia intermedia ssp. Intermedia	intermediate wheatgrass	Perennial	Alien		RSC	unknown	15	25	20	50	50	
Graminoid	Poaceae	Bromus carinatus	mountain brome	Perennial	Native			31.7%	T	T	T			
Graminoid	Poaceae	Bromus inermis	smooth brome	Perennial	Alien	Invasive						T	T	
Graminoid	Poaceae	Dactylis glomerata	orchard grass	Perennial	Alien				T	5				
Graminoid	Poaceae	Elymus elymoides	squirrel's tail grass	Perennial	Native		native	31.7%	<5	5-10	10			
Graminoid	Poaceae	Elymus glaucus	blue wildrye	Perennial	Native		native	31.7%	5-10	10	10			
Graminoid	Poaceae	Poa secunda	Secund's bluegrass	Perennial	Native				<5					
Shrub	Ericaceae	Arctostaphylos nevadensis	pinemat manzanita	Perennial	Native				5					70

Lifeform	Family	Scientific name	Common name	Annual/ Perennial	Native/ Alien	Noxious/ Invasive	In seed mix?	% in seed mix	SK1 Ocular Cover (%)	SK2 Ocular Cover (%)	SK3 Ocular Cover (%)	OR1 Ocular Cover (%)	OR2 Ocular Cover (%)	Native Ocular Cover (%)
Shrub	Rhamnaceae	Ceanothus cordulatus	buckthorne	Perennial	Native				<5					
Shrub	Rosaceae	Purshia tridentata	antelope bitterbrush	Perennial	Native		Native	5.0%						
Shrub	Rosaceae	Rubus parviflorus	thimbleberry	Perennial	Native								5-10	
Shrub	Caprifoliaceae	Symphoricarpos mollis	trailing snowberry	Perennial	Native								T	
Tree	Pinaceae	Abies concolor	white fir	Perennial	Native				30	T	T			10-20

